CCSDS File Delivery Protocol (CFDP)

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Agenda

- What is CFDP?
- How is it useful?
- My role
- Future Plans

Summary

- **What is CFDP?**
  - International standard (CCSDS) communication protocol
  - Provides reliable file transfer over a space link
- **How is it useful?**
  - Standardize spacecraft memory loads and science data dumps
  - Reusable software and automated operations
- **My role**
  - CCSDS panel member for the past 5 years
  - Major role in development and validation of CFDP
  - The Goddard expert on CFDP
  - The Goddard lead in getting CFDP adopted by missions
- **Future plans**
  - Achieve widespread adoption of CFDP
  - Support for integrating CFDP into FSW Re-use Library

What is CFDP?

- **Delivers 'files' from A to B**
  - **e.g. spacecraft-to-ground or ground-to-spacecraft**
- **Can be used with a solid-state recorder**
  - ***Virtual filestore***
- **Reliable delivery**
  - **Automatic retransmissions**
  - **Automatic validation of received files**
- **Runs over a variety of protocols**
  - **Including Internet transport protocols (UDP, TCP) and CCSDS command & telemetry**
- **Highly configurable**
  - **Direct file transfer to L2, the Moon, Mars, etc.**
- **CFDP extensions support multiple hops**
  - **File transfer to Mars via the Moon (*Store and Forward Overlay)***

Comparison with FTP

	FTP	CFDP
Response to data errors	*Slows down to accommodate collisions*	Doesn't slow down
Retransmission scheme	"Go back n" *(big performance hit when high data rates and/or long delays are involved)*	"Selective retransmission" (high data rates and long delays are handled more efficiently)

How is CFDP useful?

- **Pre-CCSDS:**
  - **Command, telemetry, memory loads, and science data dump software is *customized* for each mission (and there are many *manual* operations).**
- **With CCSDS command & telemetry protocols:**
  - **Command and telemetry source code is *reused* from mission to mission (and command delivery is *automated*).**
  - **Memory load and science data dump software is still *customized* for many missions (and there are often *manual* operations).**
- **With CFDP:**
  - **Memory load and science data dump software can be *reused* from mission to mission (and operations can be fully *automated*).**

How is CFDP useful?
Memory loads

Pre-CFDP (typical)	With CFDP
User creates the file to be loaded	**Same**
User requests a file load	**Same**
File is sent to spacecraft *(using a mission-specific command format)*	**Same (done by CFDP)** *(CFDP data units)*
Any missing data is retransmitted **(performed by the COP-1 command protocol)**	**Same (done by CFDP)**
Spacecraft calculates file checksum	**Same (done by CFDP)**
Spacecraft checksum is compared to ground checksum *(by a person)*	**Same (done by CFDP)**
If checksum matches, file is saved *(manual entry of a mission-specific command)*	**Same (done by CFDP)**

How is CFDP useful?
Science data dumps

Pre-CFDP (typical)	With CFDP
Detector creates images	**Same**
Each image is downloaded **(as a series of CCSDS packets/frames)**	**Same (done by CFDP)** **(series of CFDP data units)**
Ground stores incoming data and tracks gaps	**Same (done by CFDP)**
Retransmission requests are issued for any missing data *(a person manually enters mission-specific commands)*	**Same (done by CFDP)**
Spacecraft retransmits requested data	**Same (done by CFDP)**
Each image is assembled **(Level-Zero processing of frames is required)**	**Same (done by CFDP)**

How CFDP works

- There is a CFDP *node* associated with each filestore.
- Each file transfer is an independent transaction.
  - There can be many concurrent transactions
- Each transaction involves 2 nodes:
  - Sender (the node sending the file)
  - Receiver (the node receiving the file)
- Each transaction has 4 phases:
  - *Send the file* – The Sender is in charge; it sends the entire file once.
  - *Handoff responsibility* – The Sender hands off responsibility to the Receiver by periodically sending an 'End-of-file' message until the Receiver acknowledges it.
  - *Fill any gaps* – The Receiver is in charge. It periodically requests retransmission of all missing data (until all data has been received).
  - *Finish* – The Receiver is in charge. It periodically sends a 'Finished' message until the Sender acknowledges it.
- At the end of each pass, all transactions can be *frozen*.
- At the beginning of each pass, all transactions can be *thawed.*
- Each transaction can be *suspended, resumed,* or *cancelled.*

My role – protocol development

- CCSDS panel member
- Implemented the protocol
- Represented the protocol as state tables
- Contributed design ideas
- Helped the group reach consensus

- Fall 2002:
  - Protocol specs published (Blue Book)
  - State tables published (Green Book)
  - Validation of protocol and state tables

My role -- achieving widespread use

- **Publicize the benefits**
  - **Taught Goddard class**
  - **Presented papers at the Space Internet Workshop and International Telemetering Conference**
- **Minimize the risks**
  - **Provide validated CFDP software**
  - **Easy access to CFDP expertise**
- **Work hard to ensure first mission is successful - GPM and JWST are planning to use CFDP**
- **Once CFDP has successful Goddard flight heritage, other missions will follow.**

My role – GPM support (this past year)

- Trade study
- Overall data system design
- Software use-cases
- Developed CFDP software library
  - Implements the whole CFDP protocol
  - Suitable for both flight and ground software
  - Includes automated test facility
- Operational scenario (demo)

Future plans

- **Publicize CFDP's benefits:**
  - Write (and publish) an Executive Summary of CFDP (CCSDS Green Book) (Summer)
  - Teach a Goddard class dedicated to CFDP (Summer/Fall)
  - Continue to present papers at conferences
- **Minimize risks to CFDP users:**
  - Complete the CFDP software library product (Summer)
  - Help integrate software library within GPM flight software prototype (Summer)
  - Lead effort to integrate software library within the ASIST ground system (Summer)
  - Investigating the integration of CFDP library into FSW Reuse Library
- **Continue consulting to GPM, JWST, and other projects (e.g. Mars Telecommunications Orbiter)**

Wrap-up

- CFDP provides reliable delivery of files across space links
- Potential benefits:
  - Standardized spacecraft memory loads and science data dumps
  - Software reuse
  - Automated operations
- The key is achieving widespread usage
  - I'm the Goddard lead
  - Good progress is being made